

# HEMOCONCENTRATION IN THE ALBINO RAT DURING ACUTE HYPOTHERMIA <sup>1</sup>

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Newly-born mammals are unable to maintain a relatively constant body temperature when that of the environment fluctuates. They are, therefore, poikilothermic. Soon after birth this condition is replaced by a homiothermic one and as a result the mammal can maintain a relatively constant body temperature even when that of the environment increases or decreases within certain limits.

This ability to maintain a relatively constant body temperature is dependent upon certain reflex physiological adjustments. Those which protect against falling temperatures include shivering, erecting the hair, increasing the tonus of skeletal muscles, increasing the rate of metabolism and altering the composition of the blood by shifting certain substances back and forth between the blood and the tissues and tissue spaces. A prominent feature of the latter is a marked shifting of water from the blood into the tissues and tissue spaces and then back again into the blood as the body temperature declines in response to severe chilling. This results first in hemoconcentration and then hemodilution. These changes are progressive and can be easily followed in dogs and other mammals of comparable size or larger. Since it was not known whether these changes in the concentration of the blood could be easily followed in small mammals, where serial blood sampling introduces the complicating factor of hemorrhage, the present study was undertaken.

## METHODS

For the purpose of this study, young adult albino rats aged 49-94 days were divided into control and experimental groups. Individual samples of blood were obtained by etherizing the rat and cutting off about two inches of the tail. After discarding the first one or two drops, a drop of blood was collected on a wax plate for determination of its specific gravity by the falling drop method of Barbour and Hamilton (1926). The next two or

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three drops were collected in a small watch glass containing sufficient dried heparin to prevent coagulation. Following a thorough mixing of the heparinized blood, the percentages of blood cell and plasma volumes were determined by filling a micro-hematocrit tube with a portion of the sample and centrifuging for thirty minutes.

The body temperature of the rats was measured by inserting a small thermometer approximately 2 cm. into the rectum. When it was necessary to maintain a body temperature at or near normal levels, radiant heat of an electric lamp was applied.

Two control groups were tested. The first consisted of ten rats, five of each sex. These animals were kept under the influence of ether for a period of one hour during which their body temperature was maintained within  $2^{\circ}\text{C}$ . of the normal by intermittent exposure to an electric lamp. Samples of blood were obtained by the method described above approximately every 15 minutes. A second control group of three male and two female rats was tested in an attempt to discover the effects of hemorrhage on the blood of the first control group. These were treated in the same manner as the first except that only two samples of blood were collected, one immediately after the anaesthetic had taken effect and the other one hour later. In order to minimize the effect of hemorrhage, only enough blood for the specific gravity determination was collected.

The five male and five female rats in the experimental group were similar to those in the control groups and received the same pre-experimental treatment. After etherization the first sample of blood was taken and tested as in the first control group. The animal was then placed in a wire hammock suspended in an ice-water bath with the head and anal regions above the surface of the water. Meanwhile a relatively constant etherized state was maintained for about one hour by intermittent application of an ether mask. When the additional samples of blood were taken, the animal was removed from the bath and the tail again sectioned.

Attempts were made to sample the blood when the rectal temperature reached  $30^{\circ}$ ,  $25^{\circ}$ , and  $15^{\circ}$ , but variations in the rate of cooling in different rats modified this sampling plan. The cooling rate between successive samplings was slow enough to allow for a gradual adjustment to the cold stimulus and not fast enough

to cause the death of the animal during the experiment. Since very little blood was present in the tail at a rectal temperature of  $15^{\circ}$ , the blood sample was obtained by quickly opening the pericardial cavity, withdrawing the blood from one of the ventricles into a dry syringe and distributing sufficient amounts of it to a watch glass containing dried heparin and a wax plate for the proper determinations. In the experimental animals, as in those of the first control group, specific gravity and hematocrit measurements were made on whole blood. When only a limited amount of tail blood was obtained, the hematocrit determination was omitted since the falling drop procedure would give a more

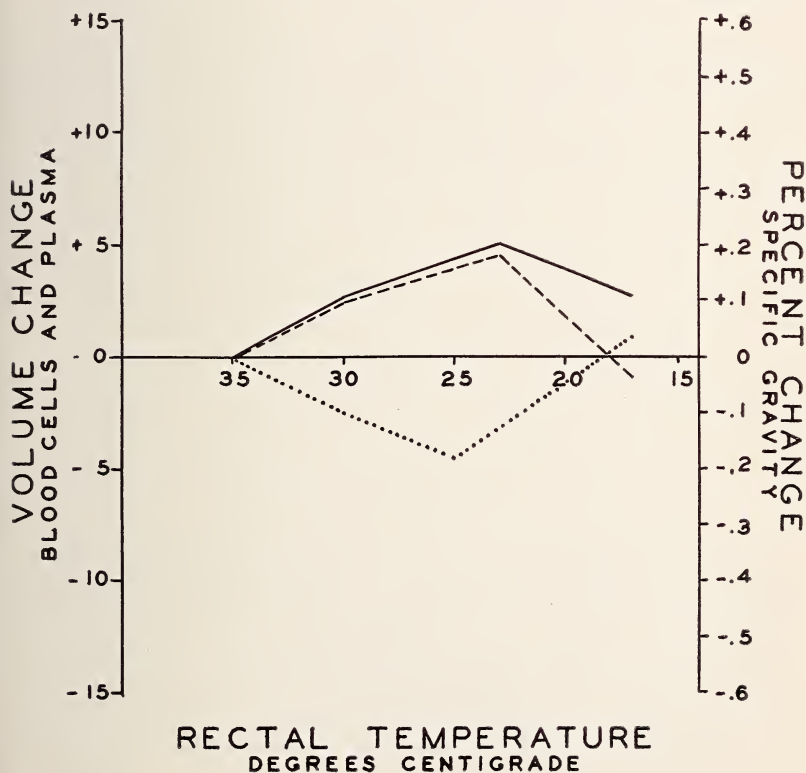


Figure 1.—The average per cent change in specific gravity (solid line) of etherized young adult albino rats with maintained body temperature compared with the average changes in cell volume (dashes) and the average changes in plasma volume (dots).

accurate measurement of relative changes in the concentration of fluids and solids in the blood.

### RESULTS

In the etherized rats of the first control group, in which the body temperature was maintained relatively constant, hemodilution rather than hemoconcentration occurred. Hematocrit and specific gravity determination showed that the hemodilution was a consequence of reduction in plasma volume (Figure 1). Since hemodilution also occurred in the rats of the second control group where there was only a very small loss of blood (Table I), hemoconcentration does not appear to be a typical response of rats to etherization as has been found in dogs.

TABLE I

Changes in the specific gravity of the blood of etherized young adult albino rats with body temperature maintained.

Rat No.	Sex	Age Days	Weight Grams	Time Minutes	Specific Gravity	Per Cent Change Specific Gravity
1	M	94	280	0 60	1.0594 1.0575	-0.179
2	F	94	190	0 60	1.0569 1.0554	-0.141
3	M	94	284	0 60	1.0621 1.0605	-0.151
4	M	68	104	0 60	1.0509 1.0476	-0.218
5	F	68	113	0 60	1.0521 1.0494	-0.256

In experimental animals exposed to cold following etherization, hemoconcentration occurred first, and then as the body temperature declined further the blood became less concentrated (Figure 2). In these experiments there was a direct correlation between the specific gravity of the blood and the blood cell volume changes.

Besides observing the changes occurring in the blood, certain other responses of rats to lowered body temperature were observed. Edema of the face and jaws was noted in several of them. The degree of edema increased noticeably as the body temperature fell below 20°C. Similar observations were made by Barbour, McKay and Griffith (1943).

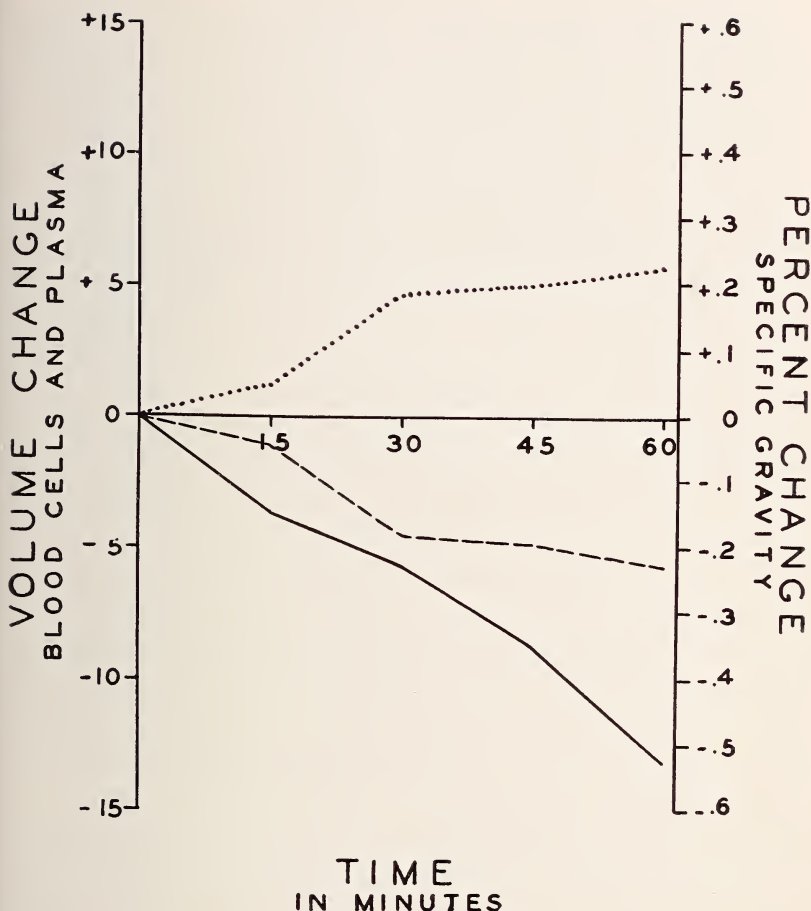


Figure 2.—The average per cent change in specific gravity (solid line) of etherized young adult albino rats exposed to cold compared with the average changes in cell volume (dashes) and average change in plasma volume (dots).

Labored breathing occurred in the control as well as the experimental animals, but in the latter, when the body temperature had fallen to  $25^{\circ}\text{C}$ . or below, breathing was slower and less laborious. At body temperatures below  $25^{\circ}\text{C}$ . ether was seldom necessary, the cold having similar anaesthetizing effects. Britton (1922) in his work on white rats and cats also found that no anaesthetic other than cold was necessary to maintain a state of anaesthesia below a body temperature of  $22\text{--}24^{\circ}\text{C}$ .

Shivering was seldom observed in the cooled rats, but peculiar convulsive movements similar to those described by Gosselin (1949) in guinea pigs were observed. These movements could often be elicited by touching the animals.

#### DISCUSSION AND CONCLUSIONS

The data obtained in this study demonstrate that white rats respond to severe chilling as do dogs (Ederstrom and DeBoer, 1947) by concentrating their blood as their body temperature declines and then, as the temperature regulating reflexes begin to fail, diluting their blood. According to Barbour and Hamilton (1925), the hemoconcentration is the consequence of water escaping from the capillaries into the tissue cells or spaces at a faster rate than that at which it enters. They believed that the cold acted directly on the arterioles, or nerves leading to them, thus causing constriction of the arterioles and slowing of the blood flow with resultant anoxemia and capillary relaxation.

The suggestion that the initial effect of cold on homoiothermic animals might cause increased cellular activity, involving more extensive oxidations and the breakdown of metabolites which would necessitate the entrance of more fluid into the cells at the ultimate expense of the blood plasma, was strengthened subsequently by the findings of Barbour and his co-workers when they found a marked increase in the metabolic rate of rats cooled to body temperatures of 26-30°C.

The hemodilution which always followed the initial response of hemoconcentration as the body temperature fell toward lethal levels appeared to be a consequence of several factors. Since the heart slowed markedly as the body temperature fell to low levels, it seemed the resulting low blood pressure was insufficient to maintain the filtration pressure within the capillaries and fluid re-entered the circulation from the cells and intercellular spaces. The re-entrance of fluid into the circulation could have been augmented also by the lowered osmotic pressure of tissue cells as a consequence of the marked decrease in metabolic rate which Barbour and co-workers demonstrated to occur in rats cooled below 20°C.

Findings of other investigators suggest that processes involved in the hemoconcentration response of dogs may be similar to

those producing this response by the administration of ether. Since the control animals used in this study did not respond consistently by concentrating their blood when given ether, albino rats apparently do not respond in exactly the same manner. It may be that the processes in rats and dogs are similar but differ in the degree they are brought into play.

Irrespective of their apparent difference in response to ether administration, both rats and dogs concentrate and then dilute their blood as their body temperature falls from normal to 15°C. or lower.

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